LLNL-TR-661063

LAWRENCE LIVERMORE NATIONAL LABORATORY

HSI Sensor Data Review, First Pass

M. E. Zelinski, P. B. Kidwell, J. R. Henderson

September 23, 2014

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

HSI Sensor Data Review, First Pass

19 September 2014

Mike Zelinski, Paul Kidwell, John Henderson

Lawrence Livermore National Laboratory

LLNL-PRES-XXXXXX

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

Summary of Findings

Scope: This is a first-pass analysis of the MSI data taken with the AISA Dual MSI sensor at the ESMF in May 2014. The objective is to assess data quality and data attributes that might impact use for anomaly detection and other observables for IFE14.

- Recommendations and Findings:
  1. It would be valuable to do a pre-flight calibration of the sensor to get gain and offset for each sensor pixel
  2. There is parallax between the two instruments, or, less likely, the timing of data acquisition is not synchronized between the two
  3. The two spectrometers have different dynamic ranges
  4. There are occasional “glitches” in the spectral profile, which might introduce artifacts in the data analysis if not corrected or screened

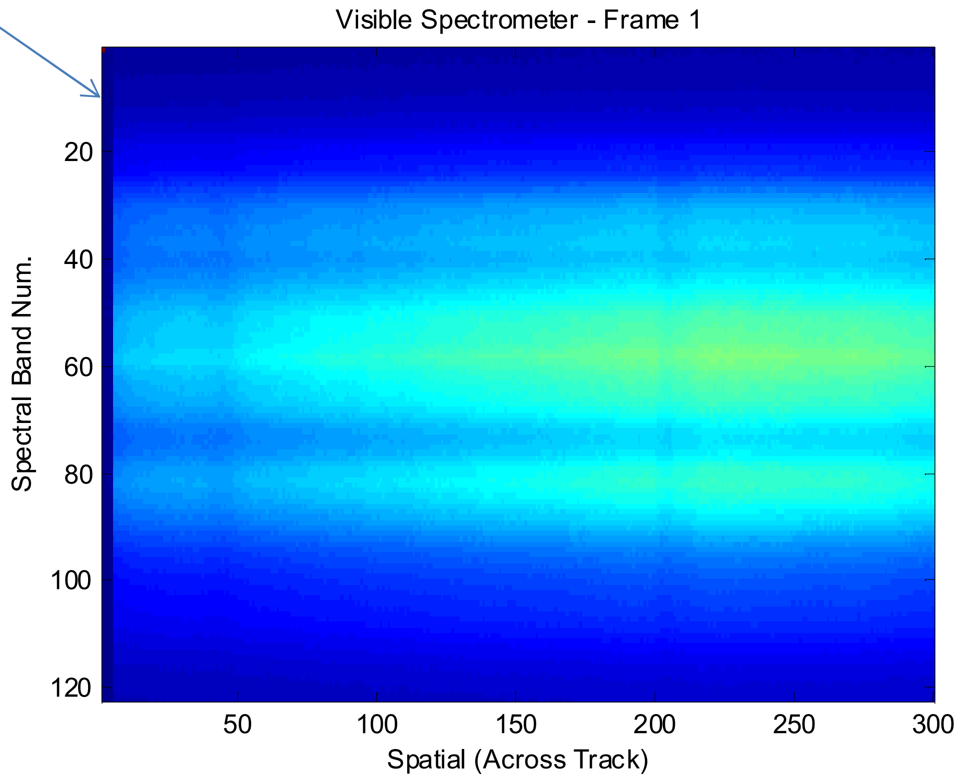
1. Value of Calibration

- A very simple calibration of the HSI sensor is possible by presenting a uniformly lit bright target to the sensor, and a uniformly “lit” dark target (such as by covering the aperture with a dark cloth).
- Background: the AISA Dual spectrometer is operated in a pushbroom mode, so the detector records spatial information in one dimension and spectral information in the other. The second dimension of spatial information is acquired as the platform moves across the scene.
- The value of this is to provide normalization of the spectral response for different spatial pixels. Various algorithms look for anomalies or do image segmentation (grouping of parts of a scene by their spectral properties) using the spectral and/or the spatial information. If the gain in one part of the array is different than in another (say because of vignetting or inherent pixel response), then the same materials in two different parts of the scene may have statistically significant spectral differences without intensity gain and offset correction.

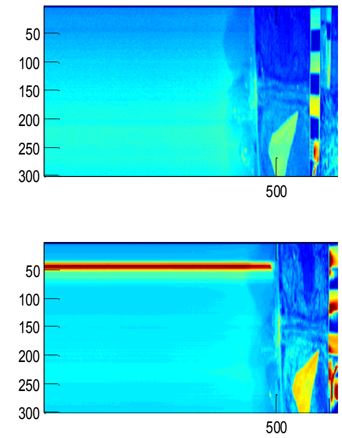
Calibration: Image analysis (1)

- The following charts show:
  - The first 4 columns of the detector in the spatial direction are non-responsive at all wavelengths.
  - Analyses of “constant” source, where the target cart is not moving and the scene is roughly constant (spatially and temporally), used to estimate the temporal stability of the detector, and to estimate the uniformity of the detector response (gain and offset per pixel), for the “Visible” sensor (400-960 nm) and the “NIR/SWIR” sensor (960-2450 nm).
    - Note that the greater signal intensity in the center of the detector suggests (but does not prove) that there is vignetting in both the spatial and spectral dimensions. Use of a spatially uniform calibration source would resolve this question in the spatial dimension. A spectrally flat calibration source (or light and dark pair of sources) would resolve this question in the spectral dimension. The need for a spectrally flat calibration source is discussed in the last bullet of the dynamic range discussion (last bullet for 3rd Finding on chart 14).

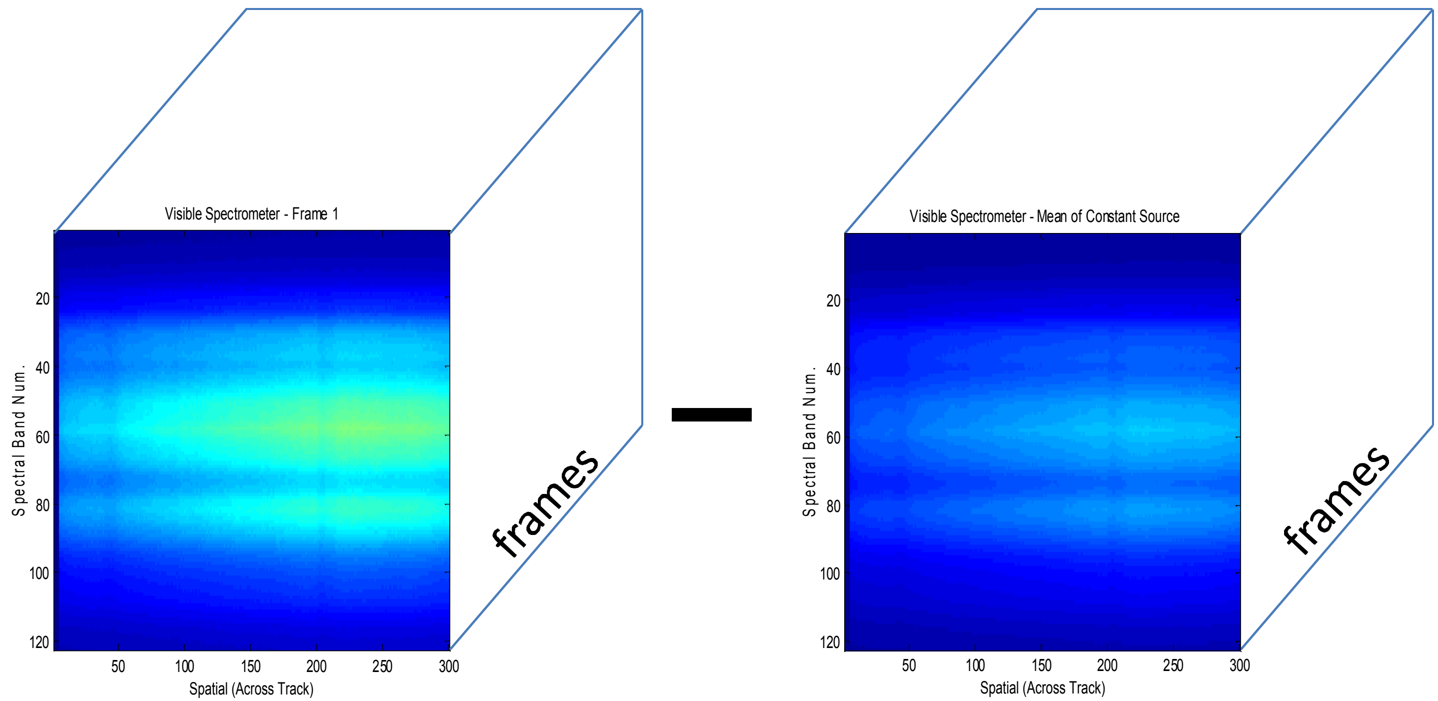
4 dead pixels in across track spatial dimension



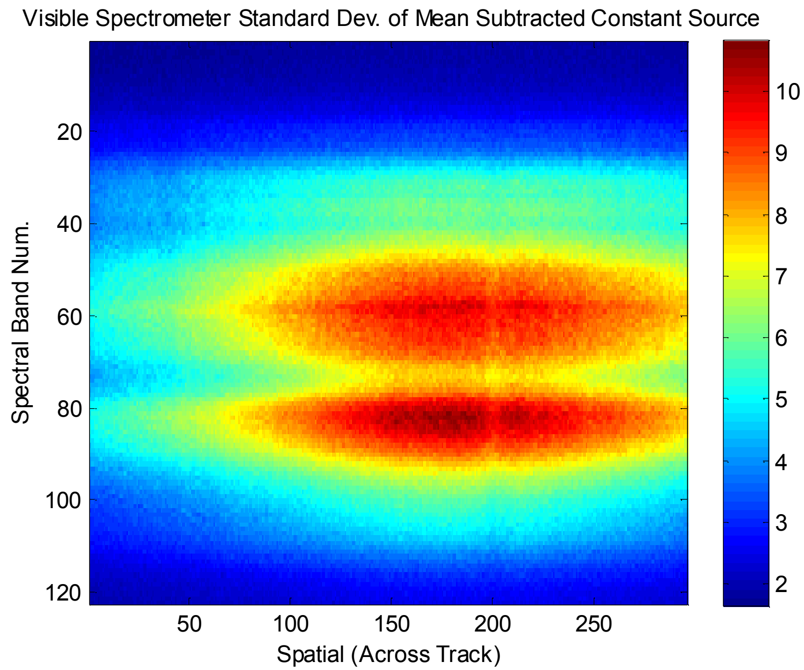
Many of the frames in our cube are of a constant source. This can be used to tell us something about the noise character of the sensor when viewing constant sources.

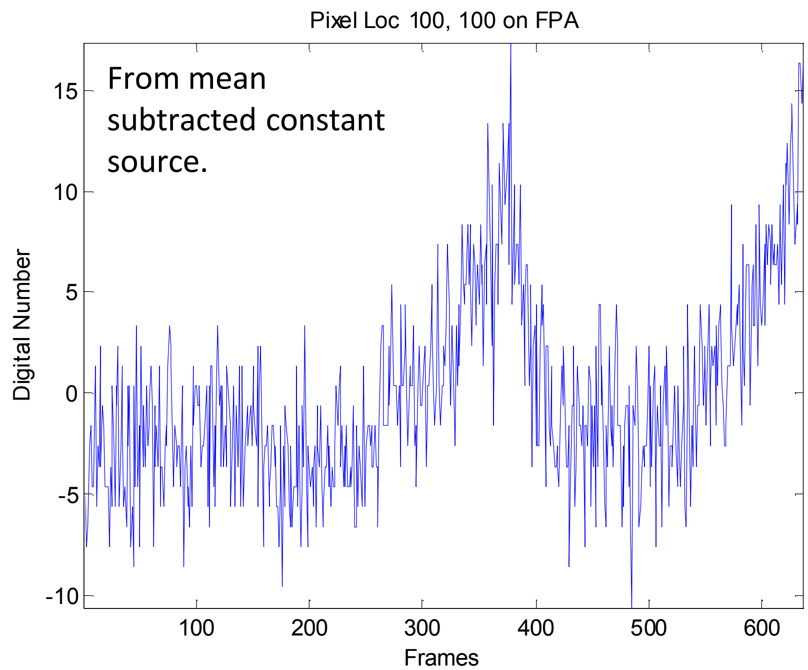


Frames 1:375 and 2000:2260 are of a constant source.

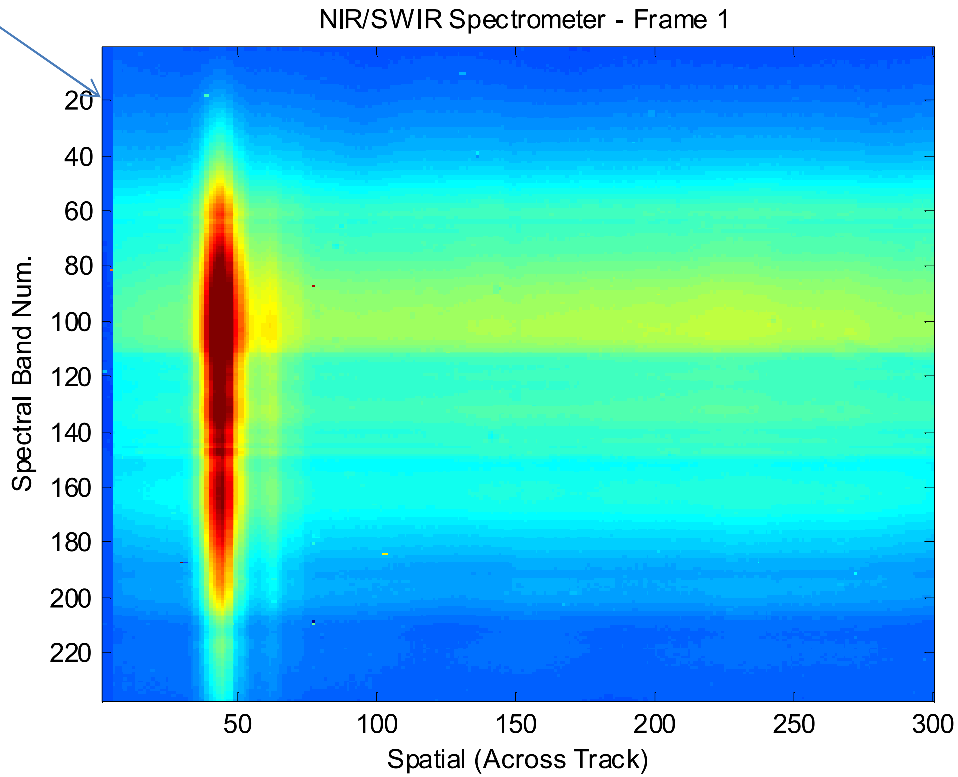


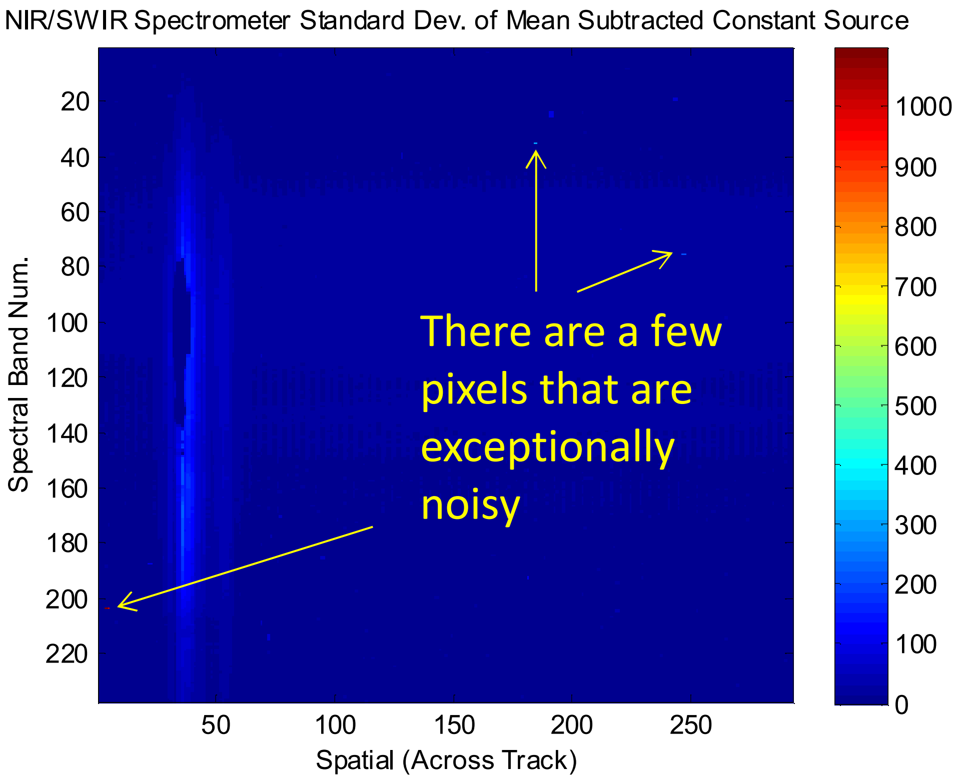
The visible spectrometer's radiometric calibration does appear to be temporally stable for much (of what is thought to be) the constant source. Some of this error could be caused illumination changes within the imaging environment.

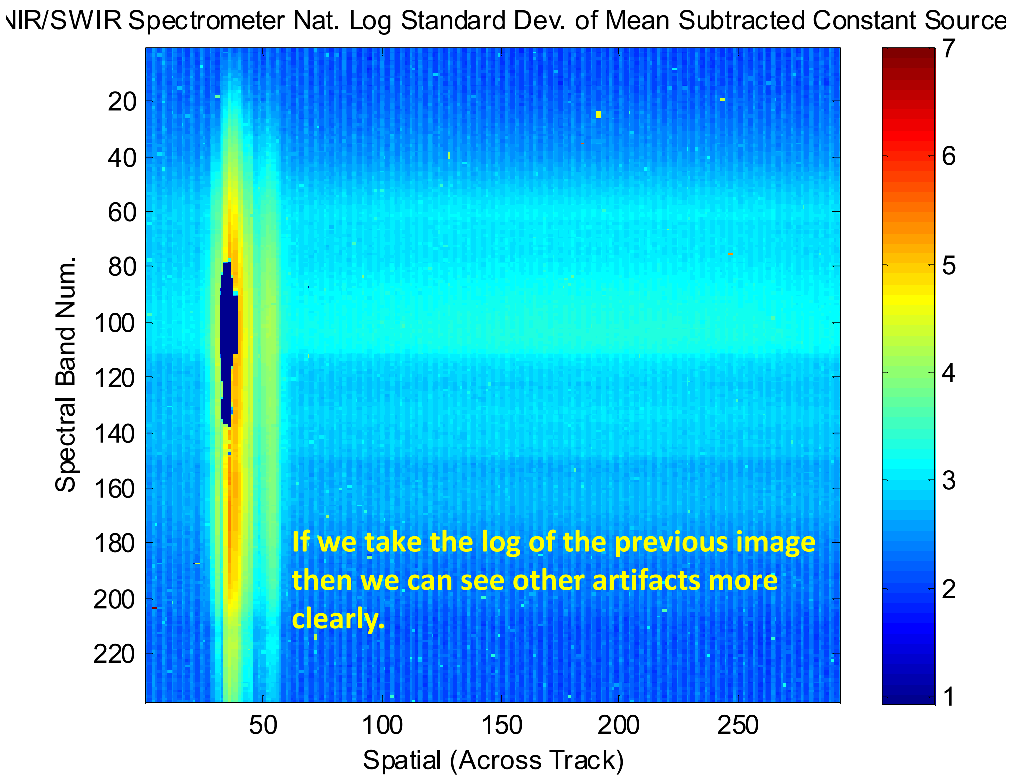


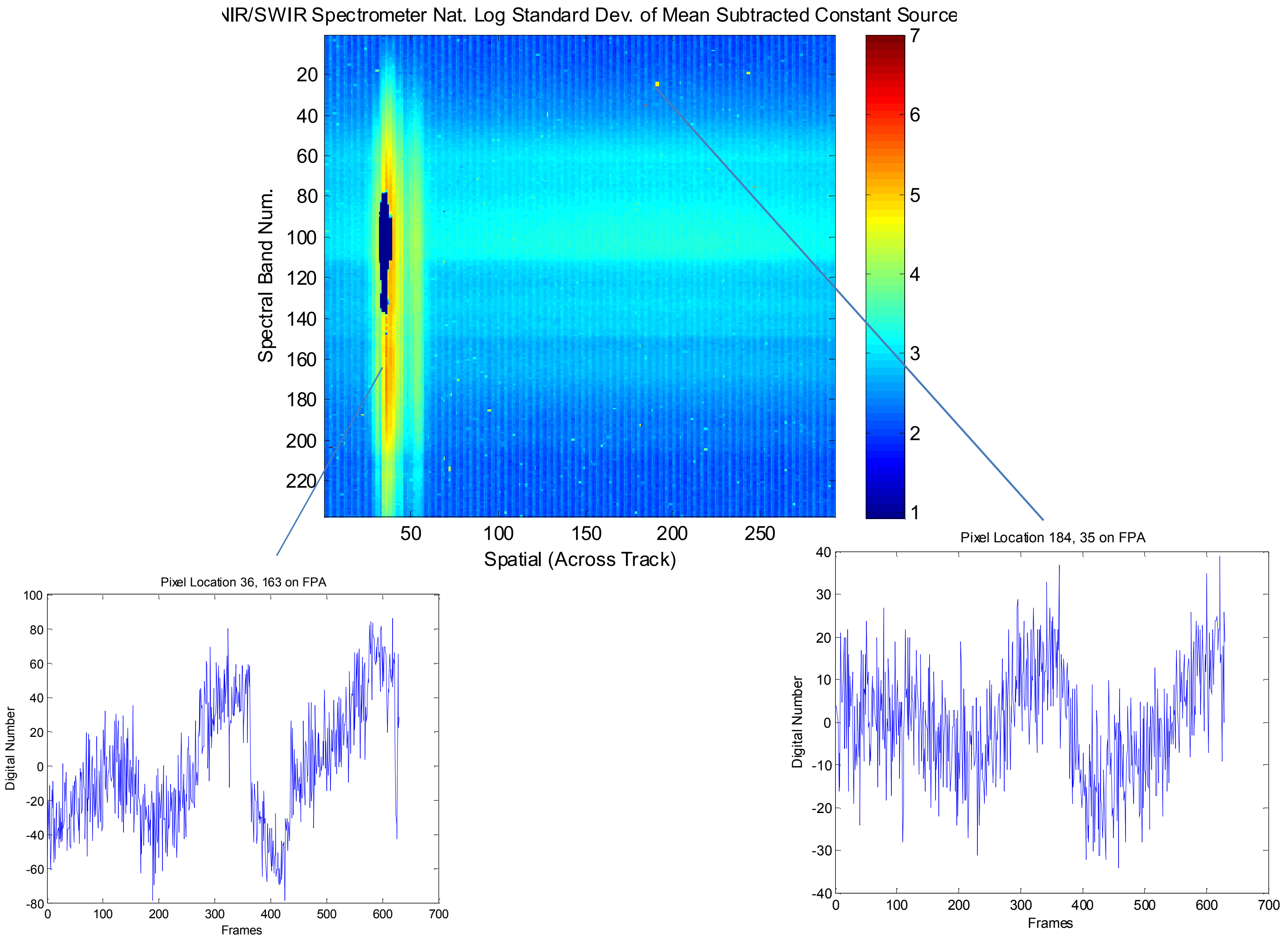


4 dead pixels in across track spatial dimension




NIR/SWIR Spectrometer Standard Dev. of Mean Subtracted Constant Source
Spectral Band Num.
20
40
60
80
100
120
140
160
180
200
220
50
100
150
200
250
Spatial (Across Track)
1000
900
800
700
600
500
400
300
200
100
0
There are a few pixels that are exceptionally noisy


NIR/SWIR Spectrometer Nat. Log Standard Dev. of Mean Subtracted Constant Source
Spectral Band Num.
20
40
60
80
100
120
140
160
180
200
220
50
100
150
200
250
Spatial (Across Track)
7
6
5
4
3
2
1
If we take the log of the previous image then we can see other artifacts more clearly.


NIR/SWIR Spectrometer Nat. Log Standard Dev. of Mean Subtracted Constant Source
Spectral Band Num.
Spatial (Across Track)
Pixel Location 36, 163 on FPA
Digital Number
Frames
Pixel Location 184, 35 on FPA
Digital Number
Frames

2. Parallax / timing

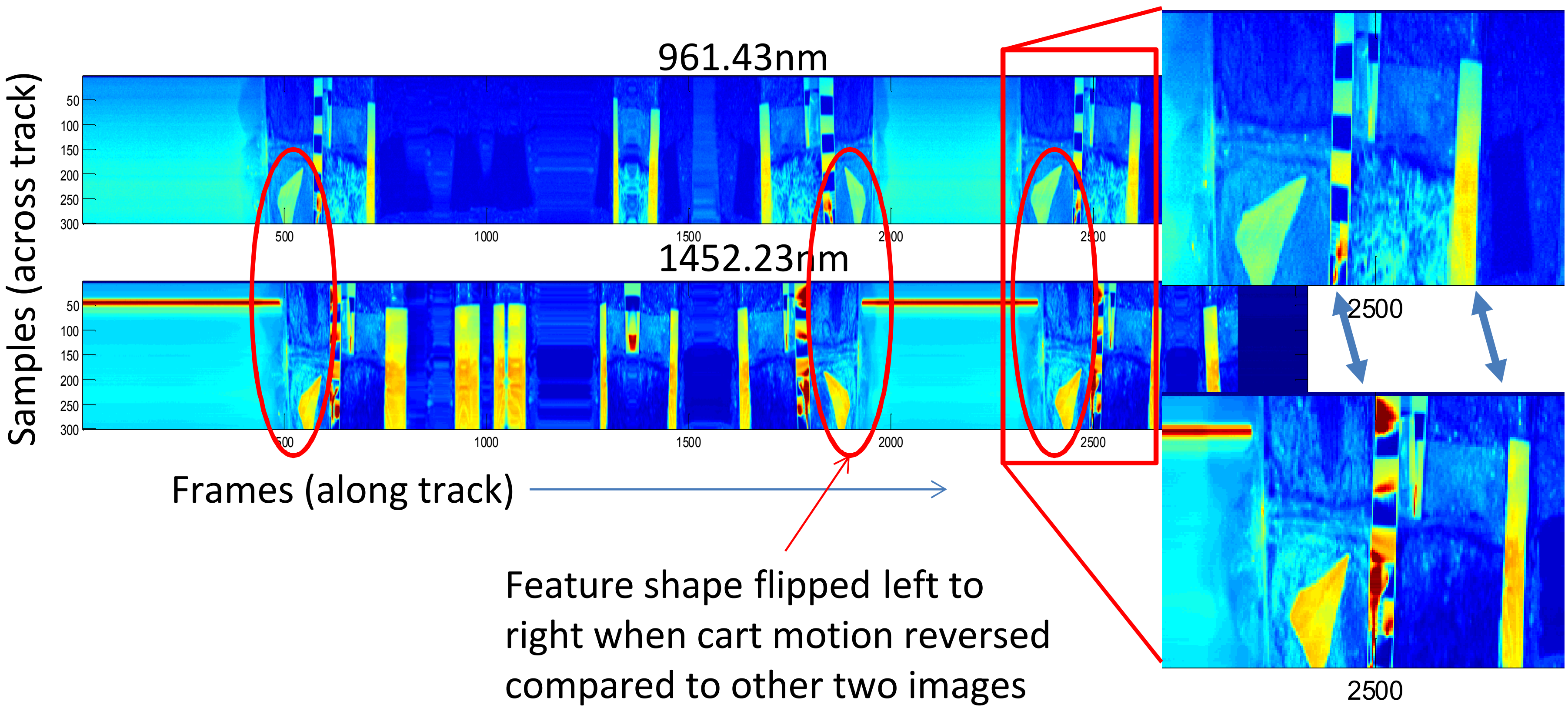
- The data on the next chart shows that features in the VNIR instrument (400 nm to 960 nm) appear before showing up in the SWIR instrument (960 to 2500 nm) for motion in one direction (see feature around frames 500 and 2400), and the opposite when the motion is reversed (same feature around frame 1850).
- This is most likely due to parallax in the instruments due to the apertures of the two instruments being located fore and aft of the direction of motion of the target cart, and the close proximity of the target cart.
- An alternate explanation is that there is timing variability or frame dropouts in BOTH spectrometers, but this is unlikely since the offset appears to be consistent for a given direction of target cart motion.
- The parallax should not be significant for airborne data. Analysis of the lab data may need correction for the parallax.

This data cube has 300 samples, 3028 frames, and 359 bands.

This sensor has two focal planes:

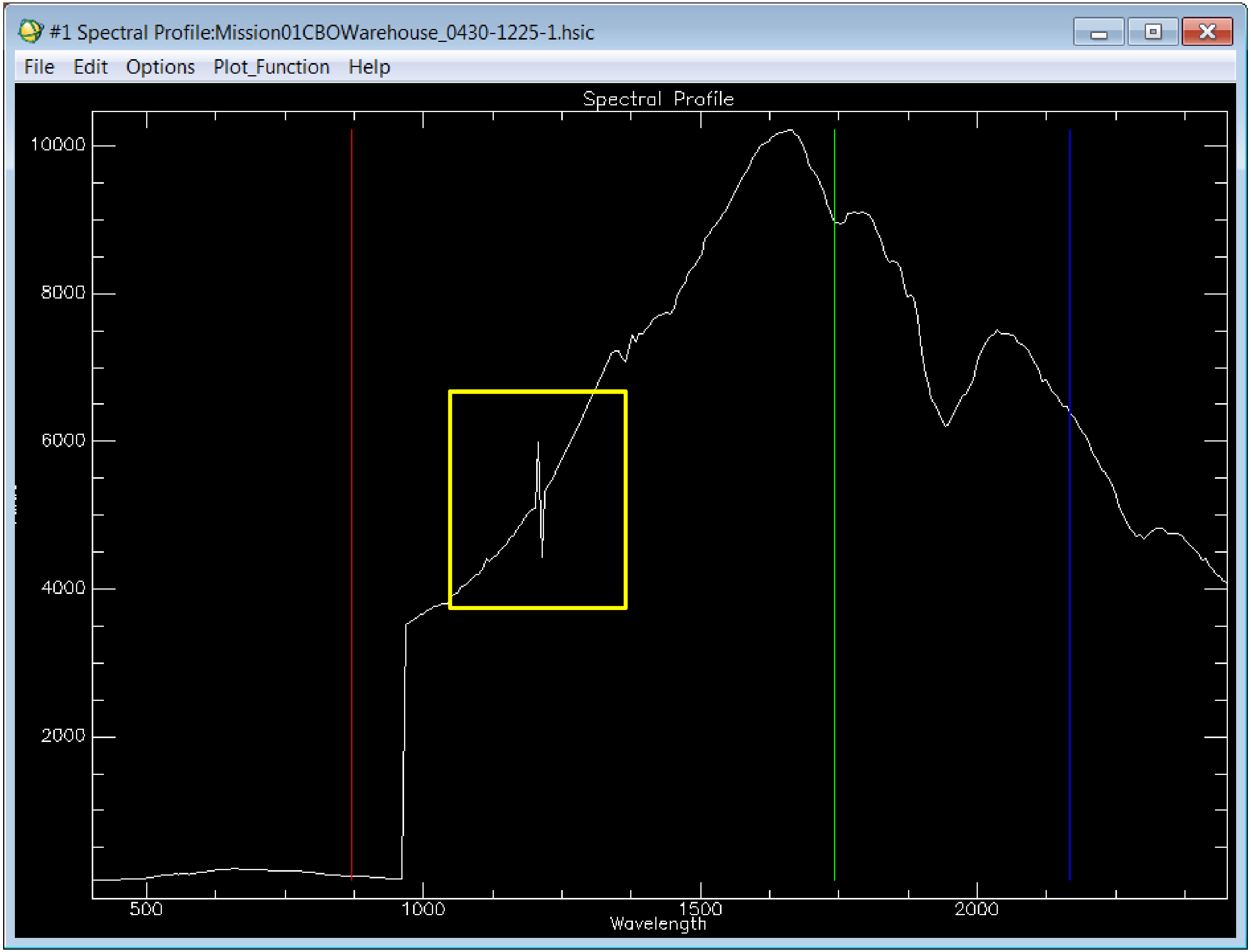
1) 122 bands spanning 400.88 – 961.43nm
2) 237 bands spanning 968.60 – 2450.89

Not how the offset of the circled feature switches when the shape of the feature is reversed due to reversal of the motion of the target cart.



3. Dynamic Range Comparison

- The data on the following chart shows the “visible” spectrometer output in digital number (DN) over the wavelength range of 400 to 960 nm, and the “NIR/SWIR” spectrometer output in DN over the range of 968 nm to 2450 nm.
- Note that the visible spectrometer DN lies in the range of about 200 to 300, and the NIR/SWIR spectrometer is in the range of 3500 to 10,000. It would be advantageous to increase the gain in the visible spectrometer by a factor of 10 to 30 to take full advantage of the dynamic range available in the digital output.
- Also note that both spectra are peaked near the center of their respective spectral ranges. This would result is a “V” shaped spectral feature around 960 nm if both spectrometers had uniform spectral response. That spectral shape is unlikely for most solid materials. The more likely explanation is that the spectral response is peaked near the center of the spectral range for each of the two spectrometers, and a correction for the (currently unknown) spectral gain and offset of each pixel would result in a smoother spectrum. This sort of calibration would also make it easier to “stitch” together the two spectra.


#1 Spectral Profile:Mission01CBOWarehouse_0430-1225-1.hsic
File Edit Options Plot_Function Help
Spectral Profile
10000
8000
6000
4000
2000
500
1000
1500
2000
Wavelength

4. Artifacts in Output

- The yellow box on the preceding chart shows an example of a “glitch,” where the output takes on non-physical values. There are a variety of methods to correct for this, but those methods must be compatible with the analysis algorithm that will ingest the data.
- For example, one can use a statistical test to find the bad values, and then use the nearest neighbors (spatially, spectrally, or both) to replace the erroneous data values. This is usually fine for visual display of the data, but can introduce correlations in the data which will corrupt the results from certain algorithms. Some algorithms can be modified to work properly with a data set where the bad values have been removed and not replaced.
- Further analysis is needed to determine what data corrections, if any, are needed for a specific algorithm applied to this data.